

**U.S. Department of Energy
Field Operations Program**

**Hydrogen Fueled
Mercedes Sprinter Van
Operating Summary**

**Cooperative Agreement
#DE-FC07-00ID-13859
Task # 4.5**

**Submitted by: Electric Transportation Applications
September, 2002**

ABSTRACT

Over the past two years, Arizona Public Service (APS), a subsidiary of Pinnacle West Capital Corporation, in cooperation with the U.S. Department of Energy Field Operations Program, has tested four gaseous fuel vehicles as part of its alternative fueled vehicle fleet. One vehicle operated primarily using compressed natural gas (CNG). The remaining three vehicles, include one pure hydrogen fueled vehicle and two vehicles fueled with a blend of compressed natural gas (CNG) and hydrogen. The blended fuel vehicles were originally either equipped with factory CNG engines or factory gasoline engines that were converted to run CNG fuel. Vehicles were modified to varying extent for operation on blended fuel and were tested using a 15-50% blend of hydrogen (by volume). The pure hydrogen fueled vehicle was converted from gasoline fuel to operate on hydrogen.

The primary objective of the test was to evaluate the safety and reliability of operating vehicles on hydrogen and blended hydrogen fuel. A secondary objective was to quantify vehicle emissions, cost, and performance. Over a total of 40,000 fleet test miles, no safety issues were found. Additionally, significant reductions in emissions were achieved with the addition of hydrogen to the fuel.

This report presents results of testing conducted over 6,864 kilometers of operation using the pure hydrogen fueled vehicle.

LIST OF ACRONYMS

APS	Arizona Public Service
CNG	Compressed natural gas
DOE	U.S. Department of Energy
ETA	Electric Transportation Applications
HCNG	Hydrogen blended with compressed natural gas

TABLE OF CONTENTS

BACKGROUND	1
APS Program Description	1
OPERATING RESULTS	2
Vehicle History	2
Emission Summary	2
Fuel Efficiency	2
Operating Cost	4
Operating Results Summary	4
CONCLUSIONS	5
Appendix A (Fuel Properties And gge's)	6
Appendix B (Monthly Mileage Summary).....	7

BACKGROUND

APS Program Description

Several automobile manufacturers are developing fuel cell vehicles. The fuel cell power plants utilized in many of these vehicles operates using compressed hydrogen gas fuel. Arizona Public Service (APS), a subsidiary of Pinnacle West Capital Corporation, has designed and constructed its Alternative Fuel Pilot Plant to gain experience with the production and dispensing of gaseous hydrogen as a transportation fuel. In conjunction with the operation of the Alternative Fuel Pilot Plant, APS operates a fleet of vehicles that operate on pure hydrogen, and a blend of hydrogen and compressed natural gas (CNG). The U.S. Department of Energy, through its Qualified Vehicle Tester, Electric Transportation Applications (ETA), has developed a cooperative agreement with APS to collect data from the operation of these vehicles.

The primary objectives for operating these vehicles were to provide "hands on" experience with the use of hydrogen, to determine the safety issues associated with dispensing hydrogen into motor vehicles and to evaluate the safety and reliability of operating vehicles on hydrogen and blends of hydrogen and CNG (HCNG). Secondary objectives were to measure the vehicle emissions, cost and performance.

OPERATING RESULTS

Vehicle History

A 1998 Mercedes Sprinter van was operated using pure hydrogen fuel in the APS alternative fuel vehicle fleet. The Mercedes Sprinter was originally equipped with a 2.4 liter gasoline internal combustion engine. The German government in Hamburg, Germany converted the engine to operate using pure hydrogen. The modifications included: adding three hydrogen tanks (115 L), CV injection, and a spark ignition modification. When the vehicle was received by APS, a WEH 5,000 psi inlet was installed to make the vehicle compatible with the APS Alternative Fuel Pilot Plant. The fuel storage tanks installed on the Sprinter operate at 3,600 psi.



Figure 1; Mercedes Sprinter Hydrogen Powered Van

Emissions Summary

As this vehicle operates using pure hydrogen, its only potential emission is nitrogen oxide. No testing for nitrogen oxide was performed on the Sprinter.

Fuel Efficiency

From the time that the van arrived at APS until June 2, 2002, it was fueled directly from a hydrogen tube trailer. No accurate fuel measurement was available from this system and thus, no fuel economy data is available for this time period. After June 2, 2002, the van

was fueled using dispensers made by Fueling Technologies Inc. (FTI). The FTI dispensers, shown in Figure 2, are equipped with an accurate fuel measuring system. The FTI dispensers receive compressed hydrogen (99.9997% purity by volume)¹ from the APS Alternative Fuels Pilot Plant.

Between June 2 and June 23, 2002, the van used 22.9 gasoline gallon equivalents (gge's) of hydrogen and accumulated 739 kilometers. The fuel economy over this time period is 20 miles per gge. This fuel economy appears to be unrealistically high. As the fuel economy was computed over a very short time period, more data should be collected to confirm these results. See Appendix B for monthly mileage reports.



Figure 2; FTI Hydrogen Dispenser

¹ Purity test conducted by Air Liquide America Corporation on 8/7/2002

Operating Cost

The Sprinter van suffered no mechanical problems during its operation at APS, and, therefore, has incurred no repair related expenses. One of the goals of the APS program was to determine if oil change intervals could be extended by the use of hydrogen fuel. During its operation at APS, the Sprinter had one oil change (odometer reading 6,719 kilometers) at the cost of \$90.00. This translates to an operating cost of 2 cents per mile. Mobil 1 Synthetic oil was used in the oil change. An oil analysis was performed on the drained engine oil to serve as a baseline for future oil analysis.² Additional testing will be required to determine actual oil change intervals.

Operating Results Summary

The Sprinter experienced only minor mechanical problems during 6,864 kilometers of operation in the APS fleet. Drivers of the hydrogen van have reported “rough” operation. It sounds similar to a diesel engine. Drivers have also reported a “dead spot” in the accelerator. The only operational problem occurred when the vehicle failed to start after refueling. It was determined that a failure to fully shut the fuel door caused the fueling interlock switch not to release. Therefore, this was an operator error. No safety problems were observed during operation of the Sprinter.

As shown in Appendix B, limited fuel use data indicate that the Mercedes Sprinter operates at 20 miles/gallon. Based upon German experience with this vehicle, this would appear to be unrealistically high fuel economy. It is believed that the short period over which fuel use measurement was available significantly reduced the reliability of the fuel economy measurement.

² Oil analysis performed by Schaeffer Lubricants

CONCLUSIONS

The pure hydrogen Mercedes Sprinter operated 6,864 kilometers in the APS fleet. The vehicle was operated to gain experience in fueling pure hydrogen. No safety problems were encountered during operation of the Mercedes Sprinter in the APS fleet. The vehicle appears to have a good fuel economy. However, this was based on very limited data and more data needs to be collected to validate the results.

Appendix A (Fuel Properties and gge's)

The gasoline gallon equivalent (gge) is a simple metric to compare the energy content in any given fuel to the energy in one gallon of gasoline. The gge values used for various fuels/fuel mixtures are given in Table 1. The value of 5.66 lb CNG was defined by the National Conference on Weights and Measures to be equal to one gge. However, no similar standard exists for hydrogen or various blends of HCNG. The listed gge's were derived from the properties given in Table 1.

Table 1; Fuel Properties and gge's

	Energy Content	Energy Content	GGE	GGE
	kWh/Kg	kWh/gal	lbm	Kg
Gasoline	-	34.5	-	-
CNG	13.44	-	5.66	2.57
Hydrogen	33.90	-	2.28	1.04
15% H2 blend	13.85	-	5.49	2.49
30% H2 blend	14.32	-	5.31	2.41
50% H2 blend	15.56	-	4.89	2.22

Appendix B (Monthly Mileage Summary)

Mercedes Sprinter Van Fuel and Mileage Summary

Date	11/1/01	12/1/01	1/1/02	2/1/02	3/1/02	4/1/02	5/1/02	6/1/02	6/23/02	7/1/02	8/1/02
Odometer (Km)	6,764	6,884	8,306	11,044	11,792	11,895	12,035	12,328	13,067	13,440	13,628
Monthly Mileage (km/mo)	120	1,422	2,738	748	103	140	293	739	373	188	
Monthly Fuel (gge)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22.9	N/A	N/A	
Fuel Economy (mi/gge)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20.01	N/A	N/A	